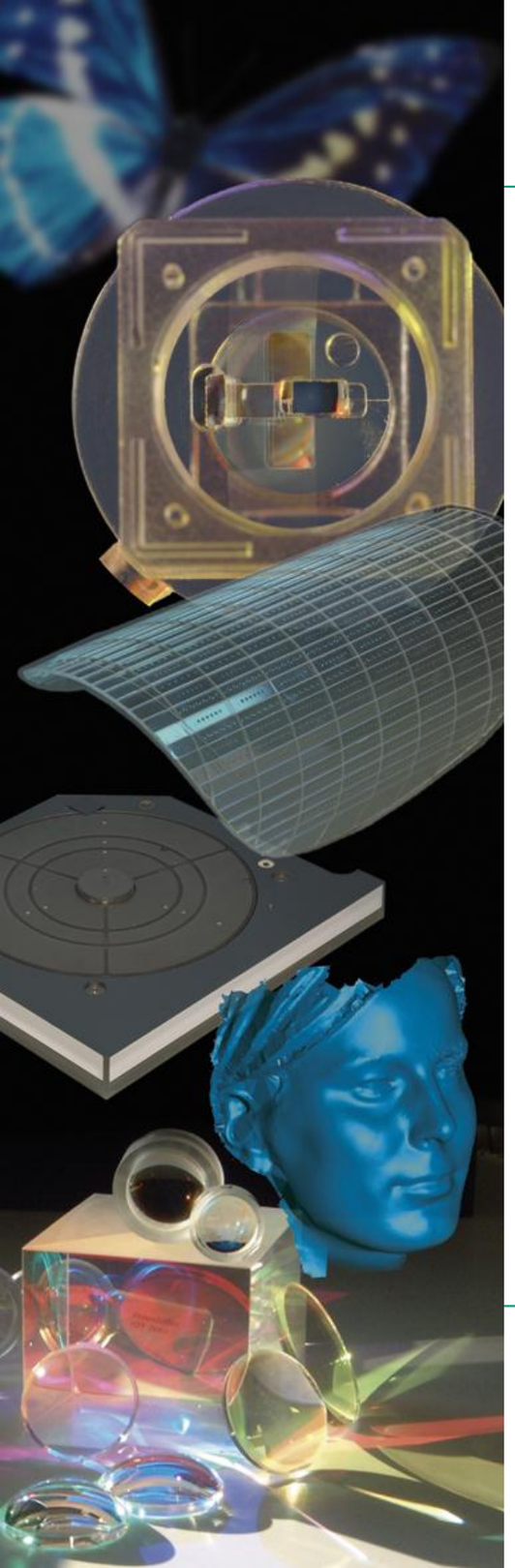
Solutions with light –
meet challenges and offer opportunities



Multilayer coating for EUV collector mirrors

2011 International Workshop on EUV and Soft X- Ray Sources

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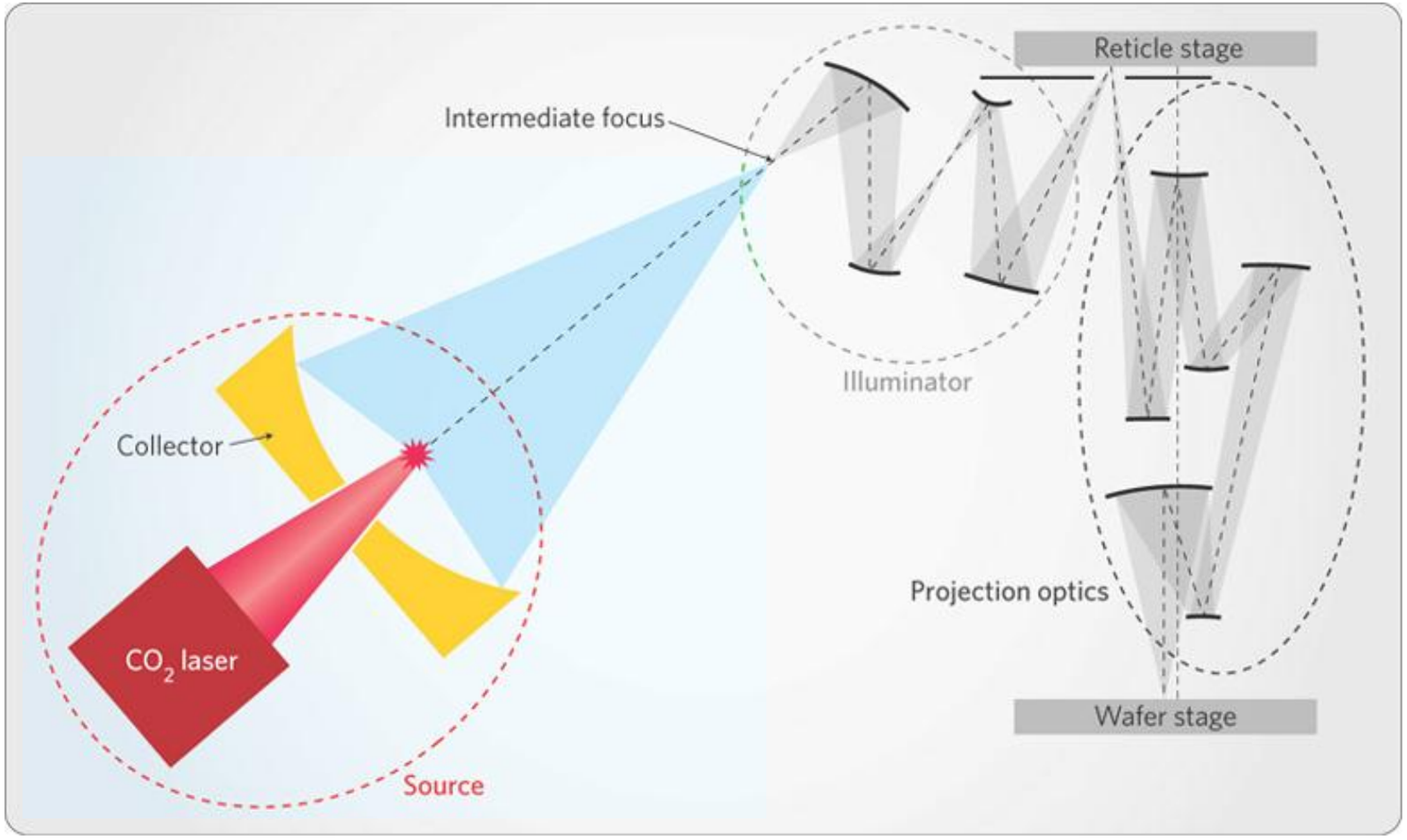
Contents

- Introduction
- Characterization of LPP collector substrates
- Multilayer coating of LPP collectors
- Summary and acknowledgement

Contents

Coating and characterization of LPP collector optics



[*Nature Photonics* **4**, 24-26 (2010)]

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LPP collector coating challenges

R > 65 %

λ = (13.5 ± 0.03) nm

→ Δd = 0.015 nm = 15 pm

- Diameter: > 660 mm
- Lens sag: > 150 mm
- Tilt: > 45 deg
- Weight: > 40 kg

LPP collector coating challenges

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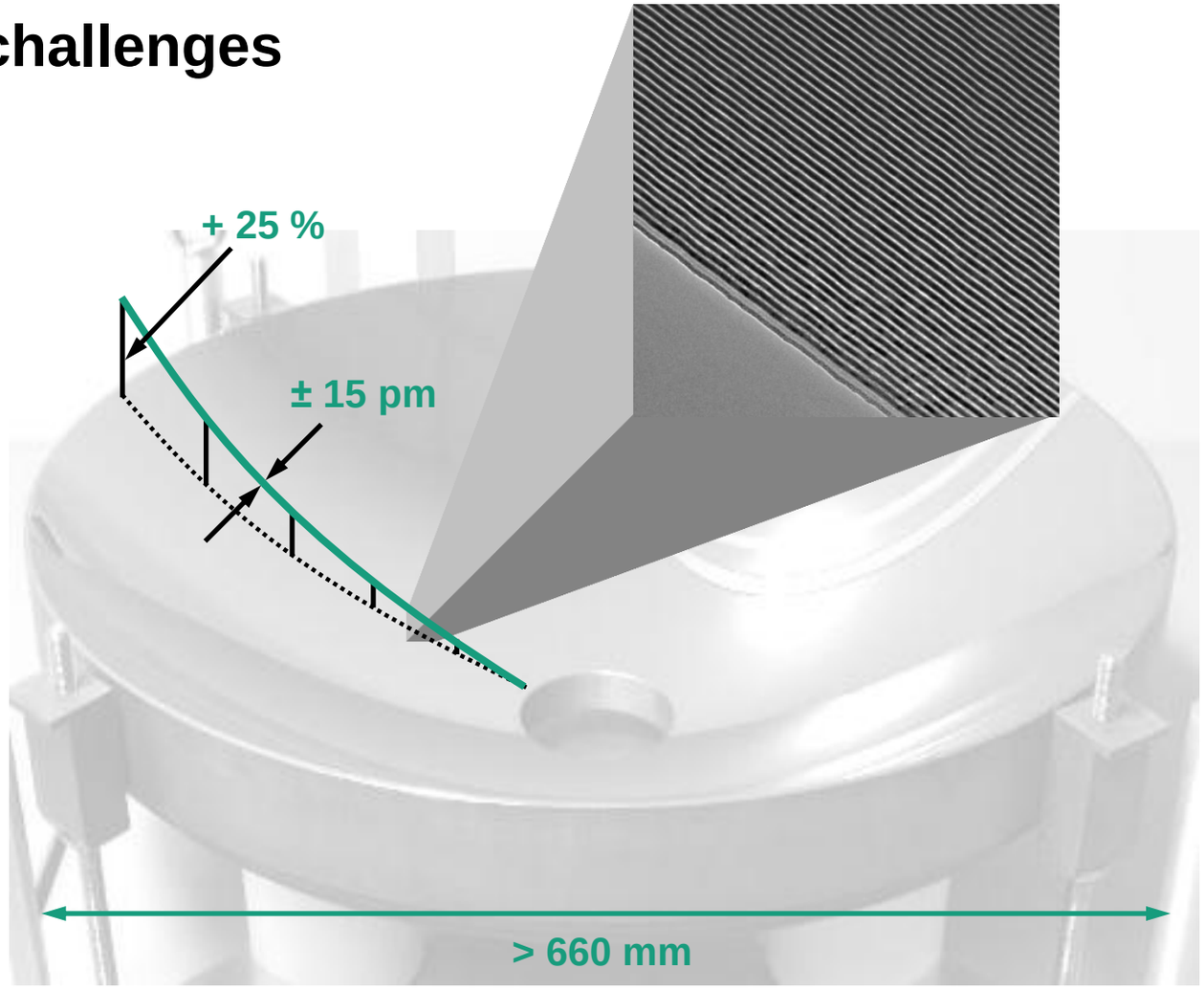
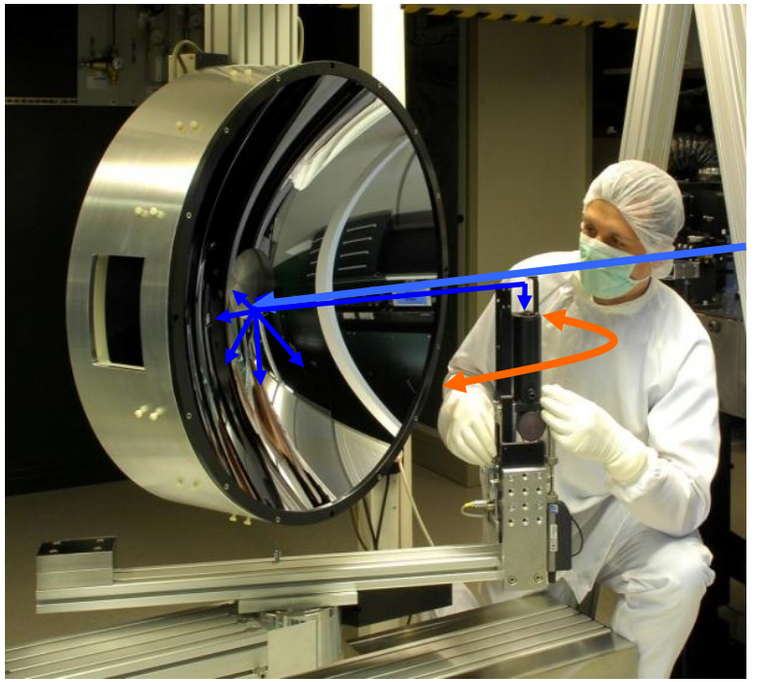


Contents

Surface characterization of EUV collector substrates

- **No robust roughness data available**
  - **Complex geometry**
  - **Required roughness sensitivity**

- **New approach: Roughness characterization through light scattering measurements at λ = 405 nm**
  - **Non-contact**
  - **Fast, robust**
  - **High sensitivity**
  - **Information about roughness, defects, homogeneity, …**



Light scattering measurements (IOF instrument Albatross)

→ Superior characterization method for EUV collector mirrors before coating

The basics: Scatter modeling of EUV multilayer coatings

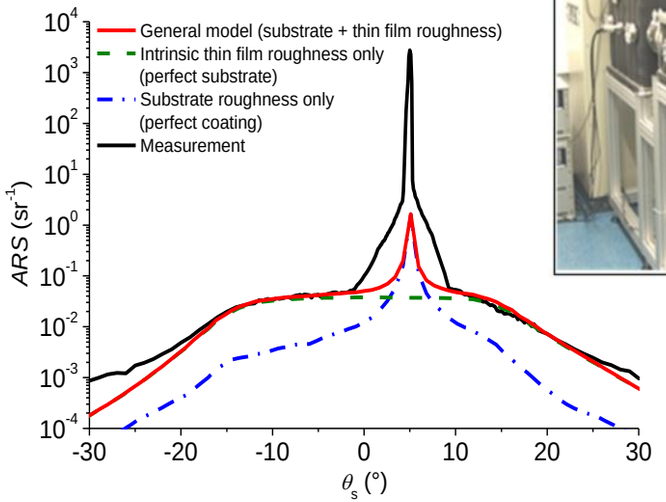
AFM measurements + modeling of roughness evolution

+

Angle resolved scattering at λ = 13.5 nm

↓

EUV scatterometer at IOF (MERLIN)



- **Separate effects of substrate and thin film ML**
- **Roughness enhancement of ML = f(substrate roughness)**
- **Influence of substrate roughness becomes dominant if HSFR > 0.1 nm**

→ **Important basis for prediction of EUV performance of given substrate before coating**

M. Trost et al., "Influence of the substrate finish and thin film roughness on the optical performance of Mo/Si multilayers," Applied Optics (2011)

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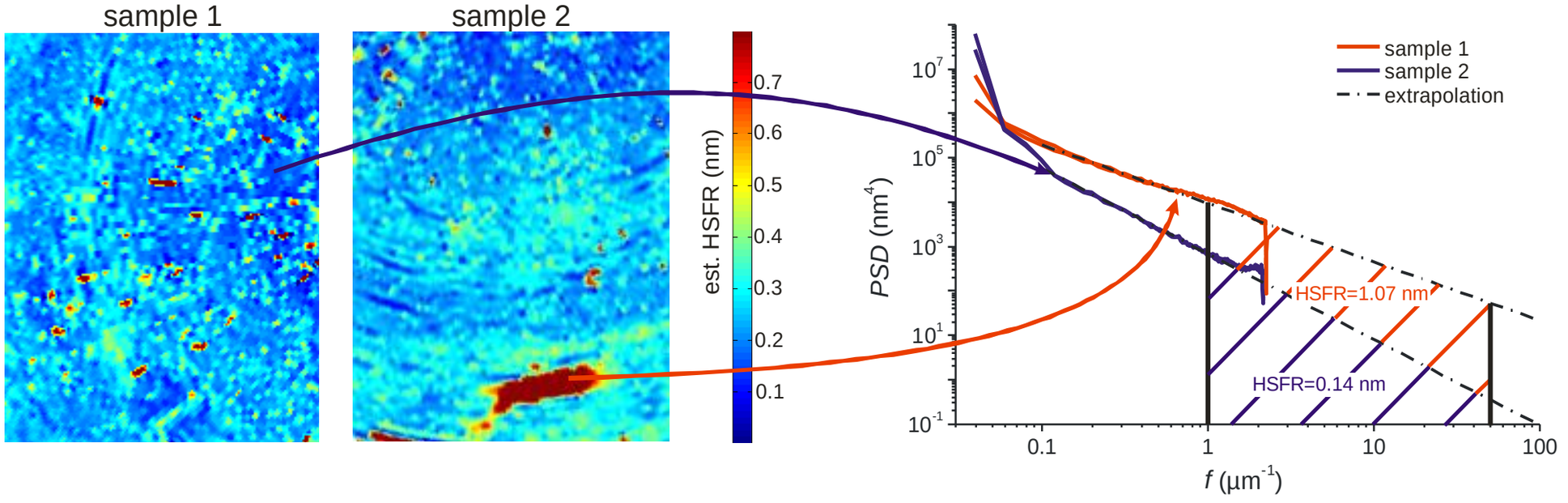
HSFR mapping from ARS measurements

PSD analysis

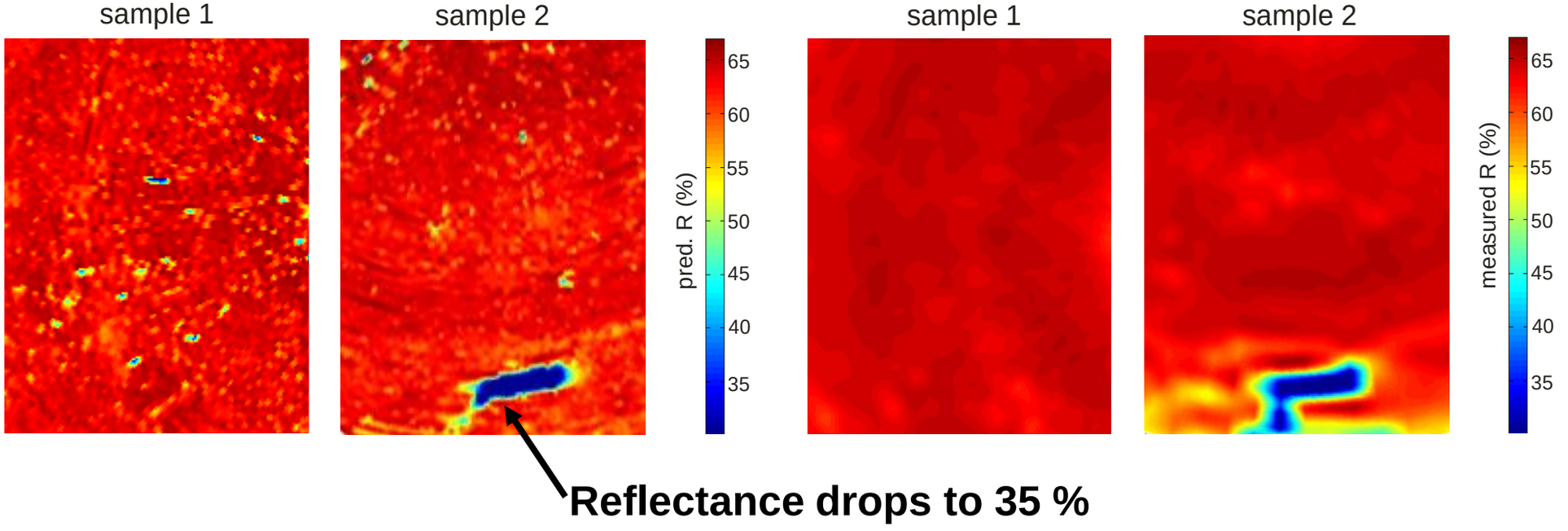


→ **Perfect fractal behavior at smooth and rough areas**

→ **Prediction of performance at 13.5 nm based on detailed roughness information (PSD, HSFR)**

Prediction based on roughness data obtained from scattering (before coating)

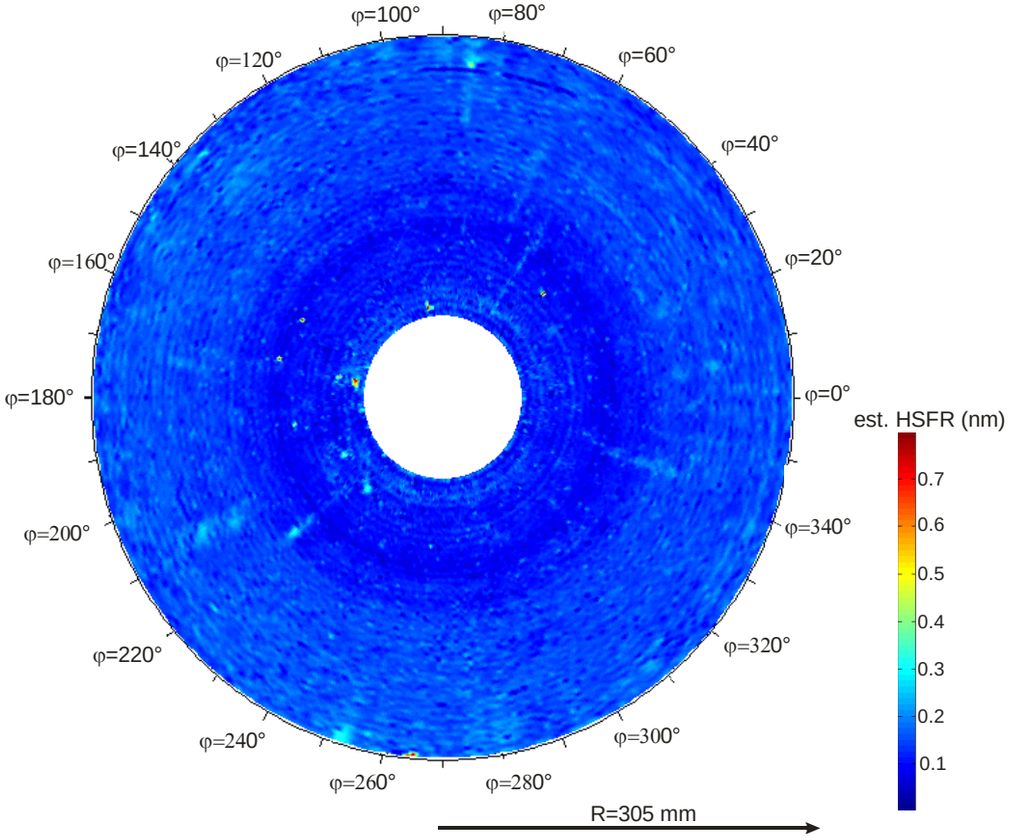
Reflectance measurements at PTB, Berlin (after coating)



Reflectance drops to 35 %

→ **Good correlation between predicted and experimental data**

→ **Accuracy of average predicted reflectance < 1%**



- **Fast data acquisition: mapping of entire sample surface (100% characterization)**
- **High sensitivity to roughness (average HSFR = 0.1 nm)**

→ **Thorough characterization of collector substrate before coating**

→ **Check for homogeneity and defects**

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Contents

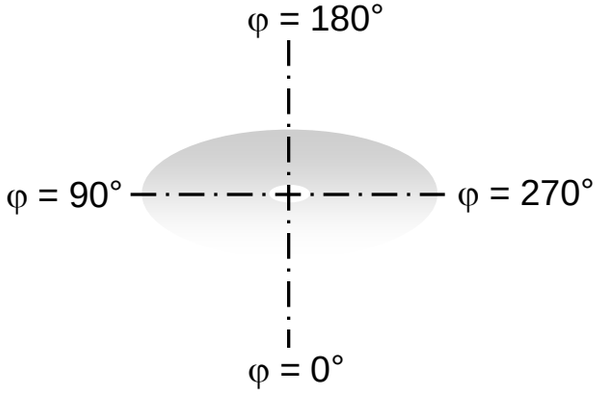
NESSY – ‚New' EUV Sputtering System

Design and realization of an EUV sputtering system

Conception:

- magnetron sputtering of rotating and fast spinning substrates **up to Ø 665 mm**
- four deposition targets
- deposition of graded multilayers on curved substrates

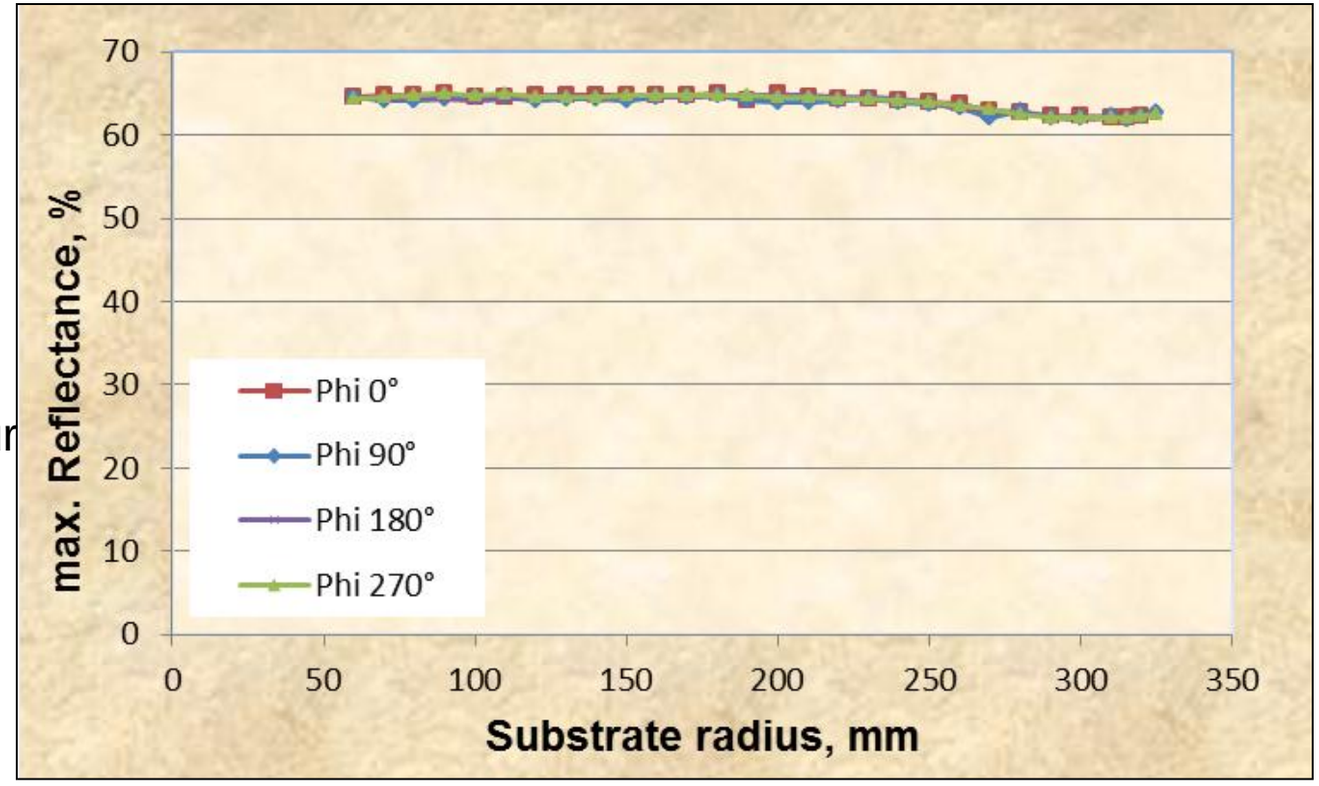
Reflectivity of LPP collector mirror



Maximum reflectance along four lines within clear aperture of collector mirror:

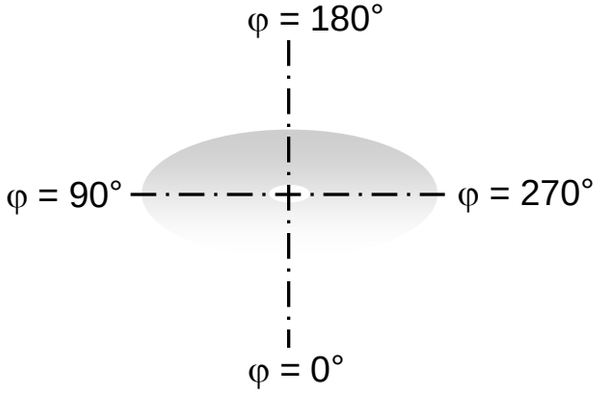
R ~ 65% @ r < 240 mm

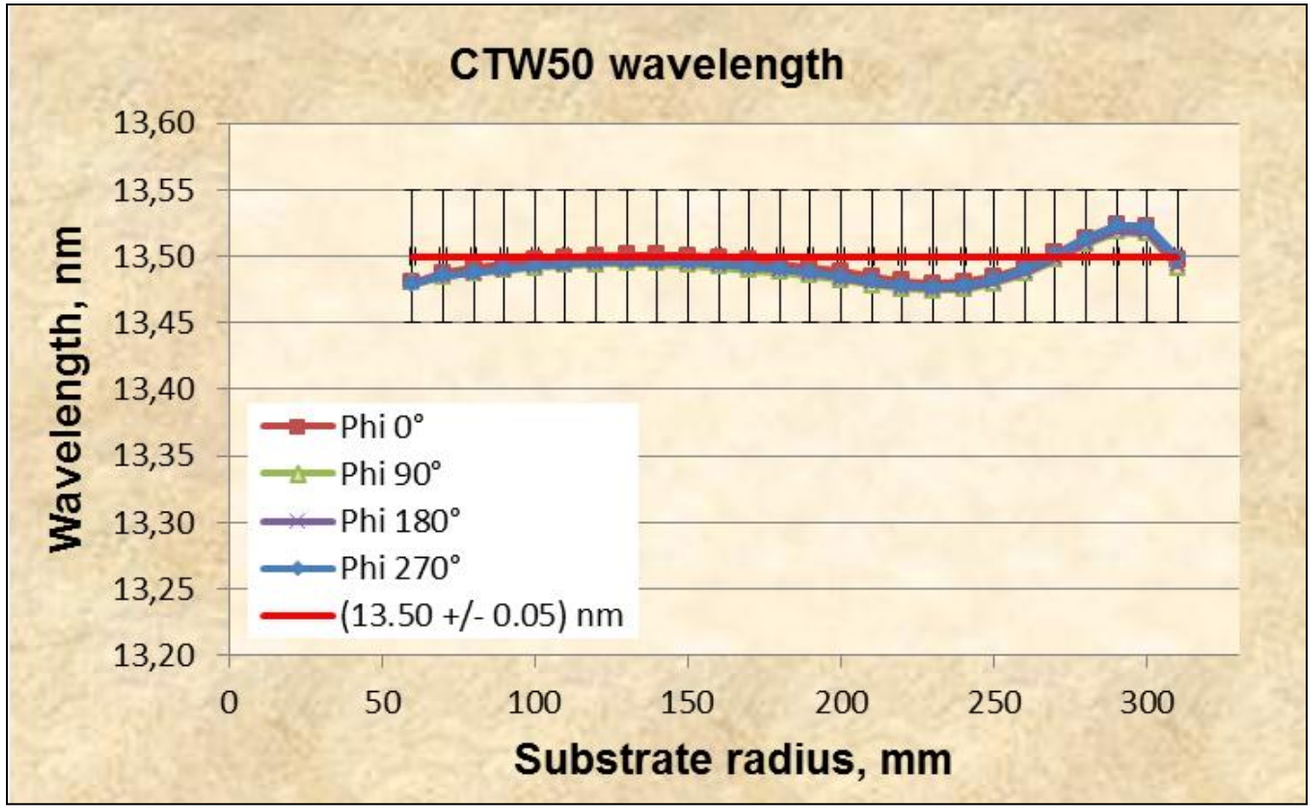
R ~ 62% @ r = 250 … 320 mm



Measurements: PTB Berlin

Reflectivity of LPP collector mirror



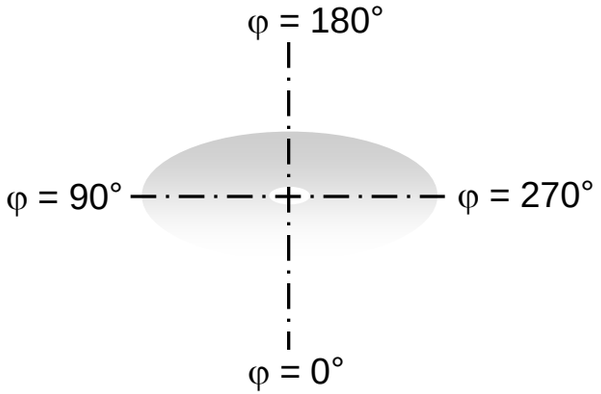


Center wavelength along four lines within clear aperture of collector mirror:

$\lambda = (13.50 \pm 0.03)$ nm

Measurements: PTB Berlin

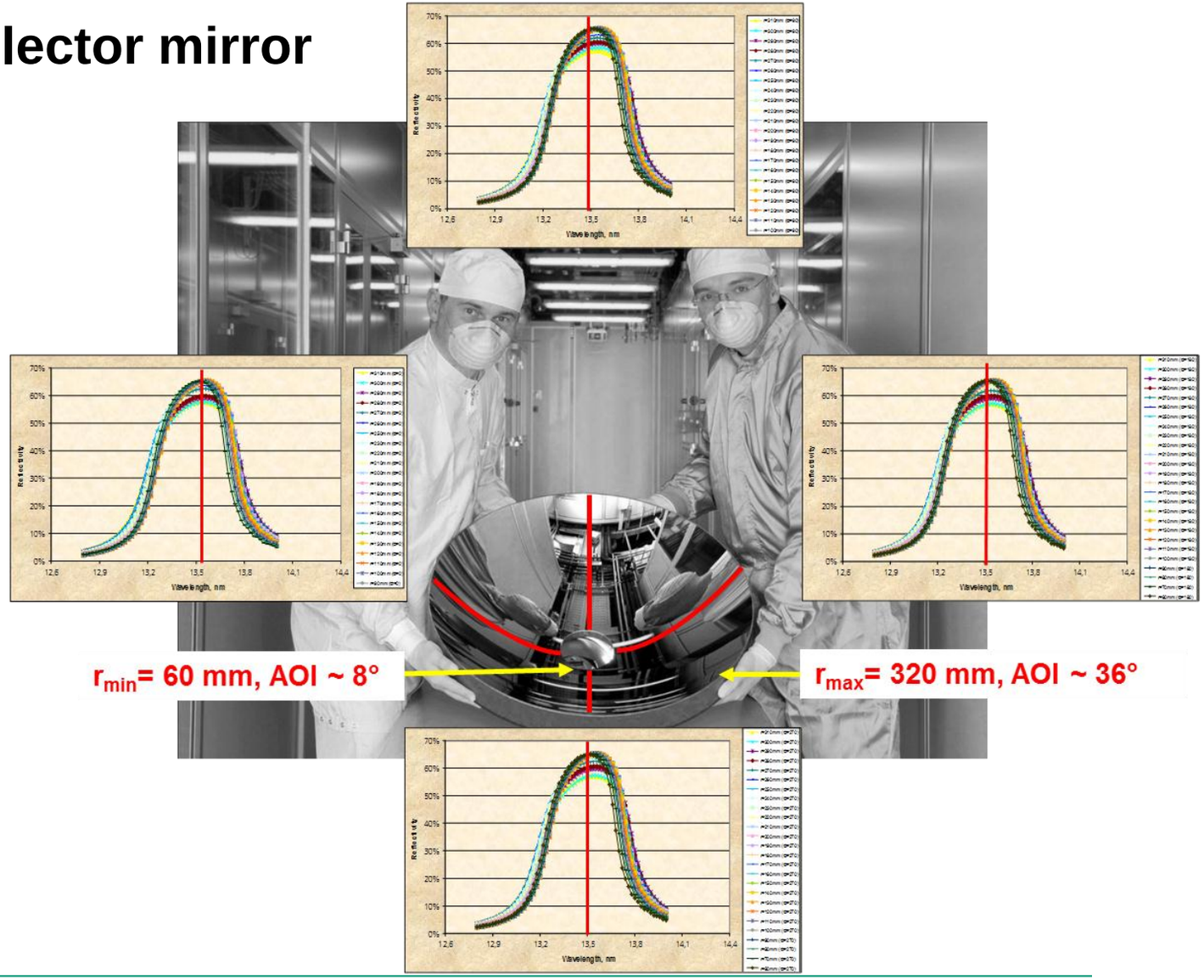
Reflectivity of LPP collector mirror



Measurement of reflectance along four lines within clear aperture of collector mirror:

108 measurement curves

Measurements: PTB Berlin



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Contents

Summary

- Characterization of EUV collector optics:
  - development of light scattering techniques for HSFR substrate characterization
  - predict EUV reflectance before coating

- Multilayer coating of EUV collector optics:
  - R > 65 % and d-spacing accuracy of $\Delta d < 15$ pm on world's largest EUV multilayer mirror (Ø > 660 mm)

Acknowledgements

- **Cymer for LPP source development:**
  Norbert Böwering, Kevin Cumming, Bruno La Fontaine, David Brandt, Igor Fomenkov, Alex Ershov, Kay Hoffmann and many others

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Thank you!